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EXTERNAL PROTON BEAM BACK STOP: MUON SHIELDING

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Dr. R. G. Alsmiller of ORNL has computed for NAL the muon isocurrent profiles which accompany this note. These curves correspond to NAL's Fe_2O_3 heavy concrete and not to some "typical" baryte concrete.

The method used for the calculation is patterned after Eyges' work. The details of the model and assumptions used are listed below.

1. Assumptions.

1.1. Only those protons which interact in the target are considered.

1.2. The pion production is taken from Trilling's work.

1.3. The pions are allowed to decay in a 5m drift space.

1.4. The contribution to the lateral spread of the muons due to the isotropic (in C of M system) pi-mu decay is taken into consideration.

1.5. The (dE/dx) calculation takes into account ionization, bremsstrahlung and trident events.

1.6. The projected range is calculated taking into consideration multiple Coulomb scattering only. Hence, the actual radial extent of the muons may be greater than the calculated one.

1.7. The isocurrent curves were made for an infinite medium but this is a small effect.

1.8. Range straggling is ignored. However, in another calculation straggling was included and the results were not altered significantly.

2. Required Attenuation.

2.1. Proton current = 1.5×10^{13} p/sec

2.2. Target thickness = 1 nuclear mean free path

2.3. Number of interacting protons/sec $\simeq 1.5e^{-1} \times 10^{13}$.

2.4. Muon flux for 2.5 mrad/hr = 21.7 muons $cm^{-2}sec^{-1}$.

2.5. Since experimentalists will work 80 or more hrs/week, accept flux for 1.2 mrad/hr, or 10 muons $cm^{-2}sec^{-1}$.

2.6. Required attenuation = $\frac{10}{10^{13}} = 10^{-12}$

3. Concrete Requirements

The pions produced in the back-stop by the protons not interacting in the target are neglected since they will be removed by reaction rather than decay.

Hence, we may integrate under a solid of semi revolution of the 10^{-12} isocurrent curve getting,[1]

$$\text{Concrete volume within the } 10^{-12} \text{ isoflux} = 2200\text{m}^3$$
$$= 7.8 \times 10^4 \text{ cu. ft.}$$
$$\text{mass} = 8800 \text{ metric tons}$$

Should it be considered convenient to operate NAL at 1.5×10^{12} p/sec, then the 10^{-11} isoflux would circumscribe the minimum necessary volume. Then minimum concrete needed for 1.5×10^{12} p/sec on target

$$\text{volume} = 1300 \text{ m}^3$$
$$= 4.6 \times 10^4 \text{ cu. ft.}$$
$$\text{mass} = 5200 \text{ metric tons}$$

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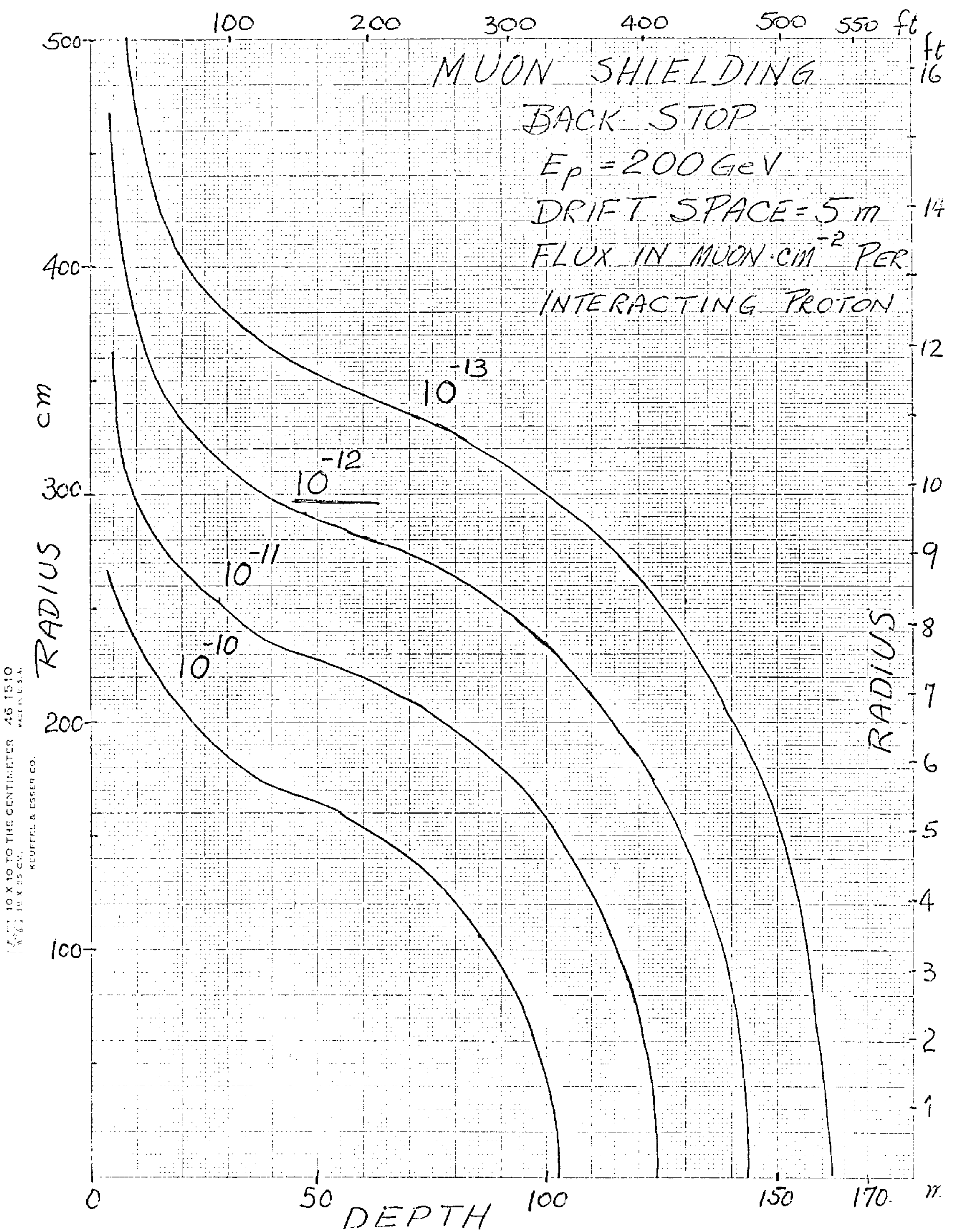
[1] Beam center line assumed at 5 ft. above floor level

Note: The above numbers assume an ideal placement of the concrete. In practice the use of modular blocks will lead to a more prismatic geometry and the volume may approximate

$$V(10^{-12}) = 4000 \text{ m}^3 = 1.4 \times 10^5 \text{ cu. ft. or } 1.6 \times 10^4$$

$$V(10^{-11}) = 2600 \text{ m}^3 = 9.2 \times 10^4 \text{ cu. ft. or } 1 \times 10^4 \text{ tons}$$

These are only order of magnitude figures.



MUON SHIELDING
BACK STOP
$E_p = 200$ GeV
DRIFT SPACE = 5 m
FLUX IN MUON·cm^{-2} PER INTERACTING PROTON
10^{-13}
10^{-12}
10^{-11}
10^{-10}
RADIUS cm
RADIUS ft
DEPTH m
100
200
300
400
500
550 ft
0
50
100
150
170
m
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